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The Multi-Dimensionality of Colors

Color has been a popular theme of philosophy for a long time, especially in the field of the philosophy of perception and philosophy of mind. When it comes to the notorious difference between primary and secondary qualities, for example, since the time of John Locke color has been dealt with as a typical example of secondary qualities. In spite of these circumstances, there have been very few philosophical investigations in which color itself is discussed as a central theme. Only recently have philosophical discussions concerning the nature of color and color vision been held, mainly within the work of analytical philosophers. These discussions have partly been motivated by the development of color sciences, which have produced various interesting results; and partly influenced by the naturalizing tendency of philosophy, in which it is widely recognized that conceptual analyses alone, without empirical knowledge about concrete phenomena, are insufficient even within the field of philosophy (cf. Byrne and Hilbert 1997).

In this sense, color and color vision now seem to have become recognized as important subjects of philosophical discussions. Nevertheless, the problems dealt with in these discussions mostly remain within a traditional conceptual scheme. For example, what is most widely discussed is the question of the ontological status of color; i.e., the question of whether color can be considered an objective property of things (objectivism or physicalism), whether it must be considered a subjective state of the perceivers (subjectivism or physiological eliminativism), or whether it is a kind of dispositional state of an object, which causes a subjective sensation in perceivers (dispositionalism).

With regard to this situation in the philosophy of color, what kind of

contribution can we find in the field of phenomenology? Surprisingly enough, at least so it seems to me, very few discussions related to this theme can be found in the present field of phenomenology. As is well known, in the tradition of phenomenology we have had important investigations concerning colors, for example, the works of David Katz (Katz 1935/1930), Wilhelm Schapp (Schapp 1976/1910), and Maurice Merleau-Ponty (Merleau-Ponty 1962/1945), to name a few. Apart from these classical works, however, we find very few contributions related to this theme in the field of phenomenology.

On the other hand, this does not mean that in the present discussions we can find no contributions that can be regarded as "phenomenological." In particular, in the new field of the philosophy of cognition, we can find various interesting attempts that can be included in the field of phenomenology. Evan Thompson, for example, criticized the dichotomy of subjectivism and objectivism, which still dominates recent discussions, on the basis of comparative studies and taking an ecological point of view, and proposes an "enactive" view of color vision, in which he defends a "relational" view of color (Thompson *et al.* 1992; Thompson 1995). According to Thompson, colors are considered "properties that depend on both color perceivers and their environment," or "they are properties of the world taken in relation to the perceiver" (Thompson 1995, p. 177). Erik Myin, J. Kevin O'Regan and Alva Noë developed a sensori-motoric account of color vision and color visual consciousness on the basis of the ecological analysis of J. J. Gibson and the phenomenological analysis of Merleau-Ponty (Myin and O'Regan 2002; O'Regan and Noë 2001). According to O'Regan and Noë, "the visual experience of a red color patch depends on the structure of the changes in sensory input that occur when you move the eyes around relative to the patch, or when you move the patch around relative to yourself" (O'Regan and Noë 2001). In other words, the identity of colors and color experiences is not independent of various changes realized by interactions between perceivers and objects, but rather realizable only through these changes.

As these philosophers take empirical findings seriously, their attempts could be regarded as a kind of "naturalizing phenomenology." However, I would rather like to find in these attempts a work of integration that brings together an ecological and a phenomenological point of view. Following this direction of their attempts and searching for the possibility of achieving an ecological phenomenology, I would like, in the following, to focus on the problems mainly raised by comparative studies of color vision.

What can we learn from the various interesting results of comparative and ecological studies? How should we interpret the color vision of other animals, which are fundamentally different and incommensurable with ours? How can a phenomenological point of view contribute to clarifying the problem of the "understanding of others" with regard to color experiences?

1. The multidimensionality of color vision in the comparative and ecological view

When the word "dimensionality" is used in color sciences, it usually means the dimensionality of the color vision of various animals, for example, monochromacy, dichromacy, and trichromacy, and so forth.

Human beings are said to be trichromatic, because most of them have three types of photo receptors in their retinas, which respond to lights of various wave lengths in three different ways, three basic (primary) colors (red, green, and blue) being needed to make a "white" color through the additive mixture of colors. Unlike human beings, a few kinds of animals such as monkeys or rats of a certain kind are considered to be monochromatic. This means that they can differentiate colors only in one dimension, just as totally color-blind persons can discriminate colors only through their brightness and see every color as if it were "black," "gray," or "white." While many mammals are considered dichromatic, certain fish and birds are said to be tetrachromatic, as they have four types of photo receptors and need four primary colors to make a "white" color through additive mixture.

Taking these results of comparative, biological, physiological, and ethological studies of color vision seriously, I would like to indicate with the concept "multidimensionality" that human trichromatic color vision is not the only possible color vision and that there is no fundamental difficulty in assuming that there are many kinds of color visions, although they are incommensurable with that of human beings.

There is another variety of color vision that is also incommensurable with that of human beings.

Bees are said to be able to discriminate the ultraviolet part of the spectrum, which is completely invisible to human beings. Although the color vision of bees is considered trichromatic, and in this sense the structure of the color space of bees is similar to that of human beings, their colors must be regarded as incommensurable with those of human beings.

As one of their primary colors includes factors that are invisible to human beings, every color that is constituted of this primary color must also be regarded as different from the colors that human beings see, even if many of the colors that human beings and bees see overlap over a wide spectrum. In addition, bees use a compound eye and polarized light for discriminating tasks. In this sense, ultraviolet photographs of flowers, which are sometimes used to display features that are visible to bees and invisible to human beings, are rather misleading, because they do not show exactly how flowers appear to bees but rather show how these features look to us (Matthen 1999, p. 81).

In any case, there seems to be no fundamental difficulty in assuming that other species of these kinds live in a world of color that is fundamentally different from our world of color.

The basic presupposition of this way of conceptualizing color vision is that the animals have developed their color vision through an evolutionary process of adapting themselves to certain environments in which they live; and that therefore this color vision has an ecological validity, whether it be dichromatic or tetrachromatic, or whichever part of spectrum the animals respond to. In this sense I would like to call this concept of multidimensionality an ecological concept of "multidimensionality" of colors.

One of the most interesting consequences derived from this ecological view of color is that the functions of color vision are various across different animals. This means, in other words, that there is no single property that all animals with color vision detect.

According to J. J. Gibson, at the ecological level of ontology, there are three major factors, i.e., medium, object, and surface. Of these factors, surface is especially important, as various affordances are detected from the properties of surfaces. Therefore, surface perception plays a central role in the ability to live in a certain environment. In this context, we

can also understand why color constancy is an ability that has been developed in many animals including human beings. If we had no such ability and instead saw constantly changing reflected lights corresponding to changes of illumination, we could never determine the property of the surface of objects through color vision.

On the basis of this important role of surface and surface perception, objectivists have claimed that the role of color vision lies in detecting an invariant objective surface property that is physically realized, and that therefore color can be identified as a surface spectral reflectance of objects. Gibson himself showed some sympathy for this interpretation of the concept of color (Gibson 1979, p. 24). However, Gibson, who emphasized the importance of surface and surface perception, did not forget to indicate that there are many kinds of surfaces; for example, luminous surfaces and illuminated surfaces, or surfaces of volumes as distinguished from surfaces of sheets and films, and opaque surfaces as distinguished from semitransparent and translucent surfaces, and so on (Gibson 1979, p. 31). It is clear that we cannot identify a single physical property across these different types of surfaces as a candidate for a definition of color.

Following this view, we should be aware that the role of color vision varies across various animals.

> To review the main examples: *for fish* the hypothesis is that color vision serves to highlight the contrast between foreground objects (surface color) and the background aquatic space light (volume color)… and to detect spectral emittances in the case of bioluminescent organs… *For birds*, the hypothesis is that color vision serves not only in the detection of surface reflectance, but also in the detection of silhouettes against the background sky… as well as illumination gradients during aerial navigation… For the honeybee the hypothesis is that color vision serves to detect the surface reflectance of flowers… but some have claimed that it is also involved in orientation to light polarization patterns in the sky… (Thompson 1995, p. 182.)

If a bird uses color vision to navigate in an aerial condition, color vision serves not only to detect the surface reflectance of some material object but to detect a certain orientation. If we take such an example into consideration, it is clear that there is no single objective property that is

visually detected by all animals with color vision. If this is the case, it seems to be clear that we cannot hold a straightforward objectivism of color. However, is the subjective view of color the only possible alternative?

The point of the results from comparative studies is that the function of color vision is various and the object of color vision is not singular. This does not directly mean that color vision is not objective and that color is a subjective phenomenon, because we can conceive of an alternative view, that various animals see different objects in the world through their color visions. Why can we not take this pluralistic view?

2. Anthropocentrism: a typical response of philosophers to the comparative view

In many books dealing with color sciences we often find the claim that colors are not properties of things in the world but subjective sensations that occur only in perceivers. In order to make this claim persuasive, scientists and some philosophers sometimes use examples of the color vision of other species. As seen above, rats of a certain kind are said to be monochromatic and see the world just like color-blind persons, and bees perceive "colors" corresponding to the ultraviolet spectrum, which are invisible to human beings. On the basis of these cases, colors are considered to be only relative to perceivers and in this sense subjective.

But why is this conclusion necessary on the basis of the results of comparative, ecological studies of color vision? As we have seen, what is most interesting in the ecological view is that the objects of the color vision of animals vary across different species, so that we cannot presuppose a definite objective property as an essence of color. Surely, as long as the objects of the color vision of animals vary across species, a reference to these objects can be made only through the characters relative to species. However, this does not mean that the objects themselves are subjective, much less that they are sensations that occur only in subjects. In spite of these circumstances, why is the subjective view so popular?

Let us see how the story goes.

The flower that I see now looks yellow to me, but a rat sees it as a shade of grey, as the rat is said to be monochromatic and can see only

differences in brightness. And a bee sees it as X (color), which cannot be characterized with our familiar names for colors. In this way, the same flower looks different to different perceivers. What color is it really then?

This way of thinking can be exaggerated in a much more imaginative case. If the same object looks so different, could it not be possible that objects that look yellow to us may look blue to a Martian? "There is thus a sense in which an object has (or could have) many contrary colors simultaneously" (McGinn 1983). In this stage, there seems to be no other way to understand this situation than to separate reality and appearances or objective properties and subjective experiences. We are now inclined to say that it is meaningless to answer the question "what color is it really?," as it seems that color belongs only to various subjective experiences or appearances and not to the real object.

The decisive point of this story is to be found, as you have probably already noticed, in the process in which our familiar concepts of color are directly applied to the visions of other species. How can we use *our* color concept of blue, yellow, or grey to characterize things as they appear to Martians or rats, things that we can never experience? Clearly, here is a typical case in which we overstep the boundaries of the field of applicability of our concepts, and which in this sense can be called a "transcendental illusion" as a result of "Paralogismus" in the Kantian sense.

This line of response by philosophers is one of the most typical ways to defend color realism against the subjective view of color. The important point of this Kantian strategy lies in limiting the applicability of our concepts to the range of *our human* experiences. In this sense, it can also be called an anthropocentric strategy. A philosopher like P. Hacker, for example, developed this anthropocentric strategy in a linguistic philosophical version and leveled an extensive criticism against the subjective view.

According to Hacker, color concepts are not directly applicable to the particular (private) experiences of perceivers, but are only applicable to public samples in a common language game. It is therefore meaningless to say that a monochromatic animal such as a rat sees the world as black, grey, or white, just as it is meaningless to say that a color-blind person sees the world with these colors.

> "Black," "white," and "grey" are words which belong to our color grammar. A color grammar usable by someone totally color-blind would not include these color concepts. For paradigms of grey are, for us, precisely *not* correctly used as paradigms for chromatic colors (of relatively low saturation) and vice versa… And to say that he [a color-blind person] sees them as grey is a misuse of the phrase "to see them as grey," for what does this person understand by "grey"? (Hacker 1987, p. 165.)

This is a very strong strategy by which to defend color realism, and we can find a similar one in other versions. Facing challenges from a comparative and ecological view, a physicalist such as D. Hilbert took the clear anthropocentric view that "human color vision is the paradigm that supplies the criterion for what is to count as color vision" (Hilbert 1992, p. 363) and denied "the apparent fact that color vision functions to detect different properties in different kinds of organisms" (Hilbert 1992, p. 365).

Surely this anthropocentric strategy in a transcendental vein is a very strong and persuasive one to use when criticizing the subjective view and defending color realism. However, the price that we are forced to pay for it seems to be too high. According to this anthropocentric view, various findings about the color vision of other animals cannot be considered color vision in the true sense of the word. Or, we must admit two ways of using the concept of color and color vision, i.e., one way in philosophical thinking and another way in empirical research.

Of course, it is not logically impossible to take this anthropocentric approach. However, in this view, concepts of color and of the color vision of human beings must play a normative role, so that these concepts cannot be vague or indefinite but must have a definite and homogeneous essence, with which we can determine what color or color vision is. In other words, the identity of the color concepts of human beings must be so definite and so homogeneous that every element of alterity or otherness for them must be excluded.

But what if the concept of human color vision is not so unitary and definite, but is indefinite and very heterogeneous? What if our experiences of color are so multidimensional that we cannot find a single essential character for color even within our field of color experiences?

3. Multidimensionality of colors in the phenomenological view

The word of dimensionality is used not only in comparative studies but also in the task of classifying colors in the phenomenal sense. Usually hue (red, yellow, green, blue, etc.), brightness, and saturation are regarded as three fundamental factors, and every color is considered definable by these factors in a color space. In this sense, most color spaces are said to be three dimensional, and in this space various characteristics of colors, such as uniqueness and binaryness or opponent relations between colors, are formulated.

In addition to these factors, color scientists take other factors into consideration as important phenomenal characteristics. Representative among them are affective factors, with which various behavioral response patterns are connected; or various modes of spatial appearances, such as a surface color or a film color. Nevertheless, most color scientists (and perhaps also philosophers) regard these factors of affectivity and spatiality as only secondary or subsidiary in comparison to the above mentioned three factors (hue, brightness, and saturation), which they consider essential for the definition of colors in the phenomenal sense.

Surely, if we deal with colors in a limited context, for example, colors seen through a small aperture in a psychological laboratory, it would be sufficient to identify colors only with those three factors. However, the colors that we encounter in our everyday life are so different and so various that the three-dimensional definition of colors is far from sufficient (and sometimes even not necessary). The colors we see in our everyday world are inseparable from affective, spatial, behavioral and other characteristics and, in this sense, are multidimensional. I would like to call this meaning of the concept of multidimensionality a "phenomenological" meaning, as these characteristics are focused upon and described impressively in various phenomenological investigations.

What I would like to emphasize here is that the two meanings of "multidimensionality," i.e. the ecological and phenomenological meanings, are closely related. If we presuppose that colors can be sufficiently defined in the three phenomenal factors of hue, brightness, and saturation alone, it is difficult to extend the range of application of the concept of color to other animals whose color vision is very different from and

incommensurable with ours. In contrast, if we can regard various factors other than these three factors as equally (or sometimes more) essential, the gap between our human color vision and that of other animals is lessened, and the difficulty of applying concepts of color to other animals would not be as great as it first seemed to be.

1) The affective character of colors

Under this concept of the affectivity of colors are subsumed various kinds of characters. The difference between warm and cool colors is a well-known one, and the connection with particular patterns of responding behavior has also been made thematic in various ways.

On the basis of the investigations of Kurt Goldstein, Merleau-Ponty emphasized that each color is inherently connected with a definite way of behaving. "Red and yellow are particularly productive of smooth movements, blue and green of jerky ones… Blue is that which prompts me to look in a certain way, that which allows my gaze to run over it in a specific manner" (Merleau-Ponty 1962/1945, p. 209f/242f).

Before psychological and physiological investigations were developed, philosophers and artists focused on this dimension in their own ways. One of the main themes of Goethe's *Farbenlehre*, for example, was to systematically clarify and classify this affective, esthetic, and value-laden character of colors. Goethe picked out this "*sinnlich-sittliche Wirkung der Farben*" as an important factor for artistic paintings and illustrated this multidimensional character of colors in his famous color circle.

W. Kandinsky extended Goethe's views of colors and developed his conception of abstract paintings on the basis of his view of the affective and synesthetic character of colors. According to Kandinsky, every phenomenon can be experienced in two ways, as external and internal (Kandinsky 1994 [Point and Line to Plane], p. 532). The internal quality of colors is found in "spiritual" or emotional effects, which call for a "vibration" of the soul (Kandinsky 1994 [on the Spiritual in Art]).

Michel Henri reinterpreted Kandinsky's view of colors in his own metaphysical framework and formulated the distinction between the internal and the external in an extreme and absolute way. According to Henri, the affective and spiritual internal dimension of colors is considered to be a dimension that belongs to the world of life (*vie*) or to the invisible real world of subjectivity, which is totally differentiated from the

visible world. In this sense, Kandinsky's paintings are abstract, because they "express" the invisible internal pathos, which essentially cannot appear in the visible world, and not because it expresses some formal (for example, geometrical) element that is abstracted from a visible world. Seen from this view, the experience of colors, which belongs to the affective dimension, must be differentiated from the perception of colors, which belongs to the cognitive dimension.

> The experience of red is neither perceiving red objects or red color as such, nor regarding the red color as red. It is the feeling of the power of red or impression of red in us, which in fact eliminates every objective mediation from the painting… (Henri 1988, p. 131.)

Henri's distinction between the affective and perceptual dimensions seems to be too strict and too metaphysical, but his indication that the affective factors belong to the dimension of life (*vie*) is very suggestive, as we could interpret the concept of life in the original (biological) sense of the word. In evolutionary and comparative studies, we now have interesting findings that show that affective factors belong to an ancient and in this sense basic level of color vision. Here are two examples.

First, brightly colored feathers of birds are reported to have perceptual significance for behavior, especially behavior involving sexual recognition. "The perceptual significance of color for birds might therefore have an affective dimension…, for as a biological signal involved in social behavior, coloration and color vision are likely to be related to the overall hormonal and motivational state of the animal" (Thompson 1995, p. 176). From an evolutionary point of view, affective factors in our color experiences, far from having a secondary and subsidiary meaning, have had an essential role in social life.

Second, the distinction between warmness and coolness is said to be rooted in an ancient subsystem, which functions to "detect a very simple characteristic of the wavelength distribution of a spectral signal, roughly whether it is stronger in the short or the long wavelength end of the visual spectrum" (Matthen 1999, p. 54f); and which is older than, and the basis of, the subsystem that functions to discriminate distinctions in hue. Phylogenetically, the difference between warmness and coolness is more original and basic than the difference in hue between

blue and yellow. If this is the case, there should be no obstacle to admitting that an animal with this subsystem has a color vision, although it does not know any categories of hue. "Clearly the primordial subsystem has access to one of the two dimensions of our richer experience of hue. To deny that it represents the world in color seems as presumptuous as for a tetrachromat to sniff at us" (Matthen 1999, p. 55).

2) Spatiality of colors

The most interesting and important point that David Katz indicated with his famous thesis of the inherent spatiality of colors is that there are no colors (red, orange, yellow, etc.) as such. Colors are always realized in some particular spatial mode; for example, surface color, film color, volume color, luminous color, and so on. If we have three different colors, for example, luminous color orange, surface color red, and luminous color blue, we cannot easily say that orange is more similar to red than to blue. The resemblance and identity of colors cannot be determined in one dimension but are essentially multidimensional.

On the basis of this characteristic of colors, Wittgenstein emphasized the "indefiniteness" ("*Unbestimmtheit* ") of color concepts repeatedly in his later manuscripts.

> There is no such thing as the pure color concept.
> Where does the illusion come from then? Aren't we dealing here with a premature simplification of logic like any other?
> I.e., the various color concepts are certainly closely related to one another, the various "color words" have related use, but there are, on the other hand, all kinds of differences (III-71, 72,73).(Wittgenstein 1977, p. 26.)

Above all, if the concept of color is already so indefinite and various within the field of the color vision of the human beings, why is it not possible for color concepts to be equally indefinite and various across different species?

The second important point of Katz' thesis is his indication of the essential connection between spatiality and sensori-motoric activities.

For example, Katz described the difference between surface and film (spectral) color in the following way.

> The paper has a surface in which the color lies. The plane in which the spectral color is extended in space before the observer does not in the same sense possess a surface. One feels that one can penetrate more or less deeply into the spectral color, whereas when one looks at the color of a paper the surface presents a barrier beyond which the eye cannot pass. It is as though the color of the paper offered resistance to the eye. We have here a phenomenon of visual resistance which in its way contributes to the structure of the perceptual world as something existing in actuality. (Katz 1935/1930, p. 8.)

In this way, various spatial qualities of color phenomena correspond to various characters of visual kinesthesia. Colors are placed in the visual space, but this space is inherently a kinesthetic space, in which our bodily movements are realized. Here in this context, we can relate the above mentioned affective and behavioral factors to this spatiality of colors and characterize a close connection between them in the following way.

The affective and behavioral dimension is not a dimension independent of the dimension of the spatiality of colors. This means that how we are affected and motivated to a particular behavior is essentially connected with how the color appears. According to Henri's distinction, the internal affective dimension and the external perceptual dimension are inseparable.

If there is no pure concept of red as such, there can be no pure concept of the experience of the color red as such, either. There is only an experience of color realized in a particular mode of spatiality connected with a particular mode of affectivity and behavioral movements. In this sense, the concept of the so called "qualia" of colors, which is used to express a pure subjective quality of color experiences and is widely discussed in the field of the philosophy of mind, must be considered something that is fabricated by neglecting this multidimensionality of colors.

Merleau-Ponty formulated the multidimensionality of colors and color experiences impressively in the following way.

> According as I fix my eyes on an object or allow them to wander, or else wholly submit myself to the event, the same color appears to me as surface color (*Oberflächenfarbe*)—being in a definite location in space, and

> extending over an object—or else it becomes an atmospheric color (*Raumfarbe*) and diffuses itself all round the object. Or I may feel it in my eye as a vibration of my gaze; or finally it may pass on to my body a similar manner of being, fully pervading me, so that it is no longer entitled to be called a color. (Merlau-Ponty 1962/1945, p. 227/p. 262f.)

Here Merleau-Ponty pointed out four types of color appearances; i.e., surface color, atmospheric color, color as a vibration of my gaze, and color that fully pervades a person. Merleau-Ponty described these types of color appearances as if "the same color" would appear in four different ways. However, following what we have seen until now, we cannot easily say that there is some single essence through these various color appearances. In this sense, this way of describing is a little misleading. On the other hand, when we say, using the concept of multidimensionality, that red is multidimensional, it seems that we cannot but characterize various color appearances as various cases of "the same color red." However, what kind of meaning can this phrase "the same color" have, if it comprises such a variety of appearances? This is exactly the question that we cannot evade, when we take a pluralistic view. Before answering this question, I would like to look at some borderline cases of color vision, in order to extend our view of color a bit further.

3) Borderline cases of color vision

a. Why can't there be a color such as reddish green or bluish yellow?

There are several relations between colors, which seem to express not only an occasional but rather an essential character of colors. Among them, the opponent relation of colors can be taken as representative. While there is a mixed color such as greenish blue or reddish blue (purple), there is no color such as reddish green or bluish yellow. Following Wittgenstein, we could call this incompatibility of opponent colors a "grammatical" relation, which has a kind of a priori status in our conceptual system in contrast to various empirical relations. Wittgenstein described this grammatical character in the following way.

> But even if there were also people for whom it was natural to use the expressions "reddish-green" or "yellowish-blue" in a consistent manner and who perhaps also exhibit abilities which we lack, we would still not be forced to recognize that they see *colors* which we do not see. There is, after all, no *commonly* accepted criterion for what is a color, unless it is one of our colors (I-14). (Wittgenstein 1977, p. 4.)

This is an essential logic of the transcendental argument used to defend the a priori status of our color concepts, which also plays an essential role in defending color realism, as we have already seen above. If, following this argument, we can secure such a privileged grammatical relation, we could retain an anthropocentric position with regard to concepts of color.

However, even this, the apparently hardest core of our conceptual scheme of colors, seems to be challenged by some results of recent studies.

As is well known, we have a blind spot on the retina, in which no stimulus is received. In spite of this condition, we are not aware of this spot in our visual field. This circumstance is usually explained with the concept of "filling in." There is a mechanism of "filling in," which functions to "create" certain information to fill in the empty place on the basis of information given by places around the blind spot. As this mechanism functions mostly to "create" a continuity of visual field, we are not aware of this mechanism.

On the basis of this concept of "filling in," we can imagine a variety of interesting experiments. Some researchers contrived a complex device to use this mechanism and conducted an experiment to investigate the possibility of seeing the color reddish-green. What kind of color do we see, when we put a target object, consisting of two adjacent bars, one red and one green, into a place where "filling in" occurs? The following was the interesting result.

> What did the subjects see? The responses fell into three groups. Reports of the first kind were that the border area was broken into a fine-textured pattern, with pebbles of red mixed in with pebbles of green. The second set of responses was that islands of red were floating in a sea of green, or vice versa. But the third set was the interesting one. Here, subjects reported seeing something they had never seen before, and had not expected to see, but had no trouble in identifying: a field of red and a field of green merging into a reddish green region in the middle. (Hardin 1986, p. 125.)

The result has not yet definitely been confirmed, nor has it definitely been interpreted. However, it would seem too rash of us to reject the possibility of the compatibility of two opponent colors on the ground that it is not our concept.

b. Seeing with the skin

In the past few decades, a device called TVSS (tactile visual substitution system) has been being experimentally used to recover a "visual" cognition for blind people. TVSS is constituted of a TV camera and a vibrator or an electrical cutaneous display for representing the luminance distribution captured by a TV camera. A blind subject who puts this display on his/her back feels at first only vibrations on the skin, but after a period of training, especially through various active modifications of sensory impressions with his/her behaviors, he/she comes to be able to capture "visual" information about distant objects "directly."

The question is whether we can say that blind people actually see with the TVSS?

To this question, O'Regan and Noë gave the following answer. "Clearly from the point of view of the present theory, seeing is not a matter of 'all or nothing.' There are many aspects to seeing, and the TVSS provides some but not all of them" (O'Regan and Noë 2001, p. 958).

This answer clearly shows that even the question of what it is to see cannot be answered a priori and that the identity of the concept of vision is indefinite and can only be determined in a multidimensional way.

With regard to color vision, it seems to be absent in the vision of the TVSS, but it is not impossible to imagine that a blind person might be able to recognize some aspect of color with this TVSS. If this were the case, why can we not say that it is a new kind of color vision? As long as the concept of vision itself is indefinite and multidimensional, it is not particularly problematical if the concept of color vision is indefinite and if we cannot find an "all or nothing" answer about it.

In the first part of this paper, we have seen various kinds of color vision across various species. To this natural variety of color visions, we can now add new possible cases of color vision, which are artificially constituted. Who knows when the list of various types of color visions is completed? The question of what color is and what color vision is remains an open question, not only for scientific researchers but also for philosophers.

4. Provisional conclusions

Now, after having looked at a wide range of colors and color visions, we must answer the question that has been touched upon in my discussions but postponed until now. Considering the variety of colors and color visions, what then is color?

As you have probably already realized, my answer is that there is no definite answer to such a question, as there is no single essential nature of color and color vision. Every answer that has been given until now is not straightforwardly false, because it touches on some aspect of the multidimensional nature of color, but it is false nonetheless, as long as it attempts to reduce various characters to a single essence.

Perhaps the Wittgensteinian answer would be a better one. In other words, the understanding of concepts should not be based on the strict identity of concepts but on a family resemblance among various types. If we relate the multidimensional character to this answer, it will give us an interesting view of resemblance.

If we take the multidimensionality of concepts into consideration, we cannot presuppose that the usual conception of the relation of resemblance between colors is self evident. As I have already indicated, orange (luminous mode) is not always more similar to red (surface mode) than to blue (luminous mode). In a similar vein, the trichromatic color vision of human beings is not necessarily more similar to the trichromatic color vision of bees than to the dicharomatic or even monochromatic color vision of human beings, if we consider various factors (for example, affective factors) that are not directly related to hue discrimination but nevertheless must be considered important for color vision.

Color vision is a visual recognition, which uses a wavelength difference of light to pick up information of various properties of the environment in order that the viewing organism may live in it. As long as the ways in which to live in an environment are various, we must take the variety of properties into consideration as a candidate for colors and the many types of visual recognition as a candidate for color vision, jus as we have seen in various examples reported in the comparative and eco-

logical studies and also in various examples of our experiences described in various phenomenological investigations.

Wittgenstein left the following statement in his last manuscript: "The logic of the concept of color is just as much more complicated as it might seem (III-106)" (Wittgenstein 1977, p. 29). Although this statement sounds simple, it must be taken seriously, as the complexity and multi-dimensionality of colors and color visions reflect the complexity and multidimensionality of the realities of our life world, in which we live with other species.